Thermal Equilibration in an Expanding Parton Plasma *

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The approach to thermal equilibrium in relativistic heavy ion collisions is dictated by the competition between expansion and parton interactions. If the expansion is much more rapid than the typical collision time among partons, the expansion is closer to free-streaming than hydrodynamic expansion. Only at times on the order of the collision time may the parton gas reach local thermal equilibrium and expand hydrodynamically. Furthermore, the time dependence of the collision time (or the relaxation time) will determine whether the system can eventually reach local thermal equilibrium because of the competition between expansion and parton interactions. If the collision time increases rapidly with time, the parton system may never thermalize, leading only to a free-streaming limit. The collision time, therefore, is a very important quantity which in turn depends sensitively on the infrared behavior of parton interactions.

What determine the thermalization processes are the transport rates which are free of logarithmic divergences after the resummation of thermal loops. This is because thermalization is achieved to leading order mainly through momentum changes by elastic scatterings. The resultant transport times for a system near thermal equilibrium behave like

$$\frac{1}{\tau_{\rm tr}} \sim T\alpha_s^2 \ln(1/\alpha_s) \qquad (1)$$

to leading order in α_s.

For a system near local thermal equilibrium, the time dependence of the transport times is through the temperature according to Eq. (1). This dependence is in general slower than $1/\tau$ and thus can lead to local thermal equilibrium according to arguments based on the relaxation time approximation. We can solve the Boltzmann equation in the relaxation time approximation and demonstrate how the time dependence of the relaxation time will affect the approach to thermal equilibrium.

From Fig. 1, one can see that if the time dependence of the relaxation time is weaker than linear, the thermal equilibrium limit will eventually be reached. For a time dependence stronger than the linear one, the system will never thermalize, only leading to a free-stream limit. For an exact linear time dependence, the system will reach an asymptotic state between free-streaming and thermal equilibrium. We find that the thermalization process also depends on the initial condition of the system. The deviation of the initial momentum distribution from an isotropic one in the longitudinal direction determines the initial approach to thermal equilibrium. This initial approach will then carry its inertia throughout the whole thermalization process. This "memory effect" can be seen from the dependence of the final total entropy production on the initial momentum distributions.

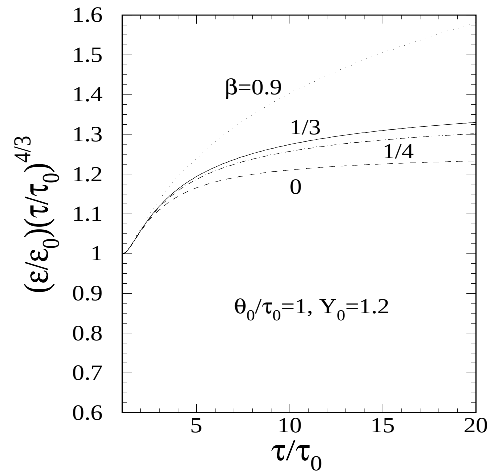

Figure 1: Time evolution of $G(\tau/\tau_0)(\tau/\tau_0)^{1/3} = (\epsilon/\epsilon_0)(\tau/\tau_0)^{4/3}$ according to the solution to Boltzmann equation, for different time dependence of the relaxation time $\theta = \theta_0(\tau/\tau_0)^\beta$, with $\theta_0/\tau_0 = 1$, $\beta = 0.9$ (dotted), 1/3 (solid), 1/4 (dot-dashed)and 0 (dashed line). $Y_0 = 1.2$ is the width of the initial rapidity distribution.

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